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EVALUATION OF DATA OBTAINED FROM
A 35 GHz PROPAGATION EXPERIMENT

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

HUNTSVILLE, ALABAMA

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FOREWARD

This is a special technical report on a study conducted by the Electrical Engineering Department under the auspices of the Auburn Research Foundation toward the fulfillment of the requirements prescribed in NASA contract NAS8-11184. An evaluation of data obtained during a propagation experiment is presented.

ABSTRACT

NG66-33443

The determination of the effect of atmospheric conditions on the propagation of electromagnetic waves has been the object of much experimental study. This report presents the results of an analysis of data obtained during a propagation experiment performed at Huntsville, Alabama. A frequency of 35 GHz was used in performing the experiment.

An empirical equation relating attenuation and relative humidity was obtained and the results of the experimental data were compared with this equation. The two were found to agree quite well in the humidity range 0-50%. Above 50% humidity, droplets begin to form which produce scattering. This scattering completely disguises any simple attenuation effects as the humidity is increased.

Author

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I. INTRODUCTION

J. L. Richardson and E. R. Graf

During the period, December 2 through December 15, a propagation experiment using a frequency of 35 GHz was performed by George C. Marshall Space Flight Center, Huntsville, Alabama. The propagation path, Green Mountain to Marshall Space Flight Center, was approximately 10 miles in length. Other details of the experimental setup are shown in Figure 1. The electric field was vertically polarized.

The data obtained consists of the humidity, pressure, temperature and relative signal strength plotted as a function of time. Measurements were taken at Green Mountain, Parkway, and Marshall Space Flight Center stations.

The purpose of this report is to present the results of an analysis of the data obtained. The analysis consisted of determining what effect the humidity, pressure and temperature of the atmosphere has on the propagation of the electromagnetic waves.

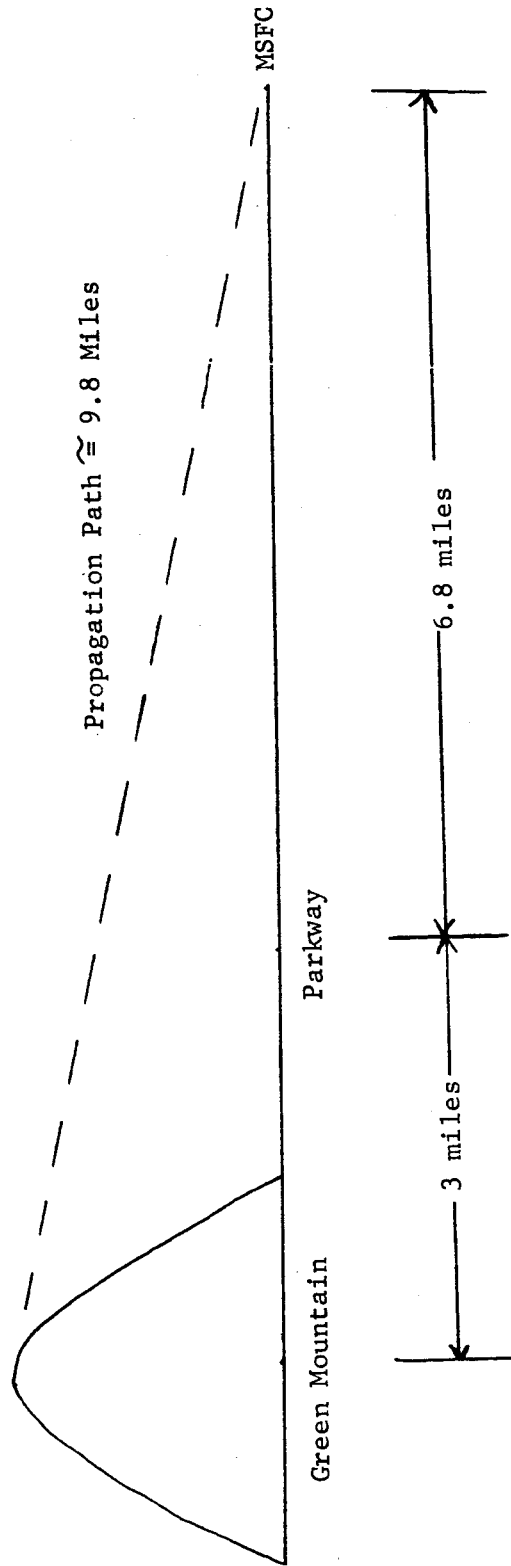


Fig. 1--Propagation setup using a frequency of 35 GHz.

II. ANALYSIS

Each of the measured variables - humidity, pressure, temperature and relative signal strength - was averaged over a period of 12 hours. These results are shown in Table I. From these results, as was anticipated, the presence of water vapor in the atmosphere was the primary factor affecting signal strength level. The pressure and temperature remained fairly constant during the experiment. In addition, it was deduced from the data that a composite average consisting of the humidity values recorded at the Green Mountain and Parkway stations was the best representation of the actual humidity conditions. These values are listed in Table II.

The relative signal strength was converted to values of attenuation (db) and plotted as a function of these composite values. The result is shown in Figure 2. An empirical equation relating attenuation and relative humidity was obtained using numerical values presented in a report by Tolbert and Dickenson.¹ The equation is

$$\gamma(\text{db}) = 4N \quad (1)$$

γ = attenuation

N = Per-cent humidity

This equation is also plotted in Figure 2.

¹C. W. Tolbert and R. M. Dickinson, "Calculated Values of Absorption Due to Water Vapor and Oxygen in the Millimeter Spectrum," Report No. 6-42, EERL, The University of Texas, 20 February 1961.

However, this very simple equation is limited in application. The attenuation represented is that presented due to the gaseous water vapor and does not take the scattering of the beam due to droplets into consideration. For this reason, as the humidity increases, a good correlation cannot be expected between experiment and calculation unless the environment is carefully controlled.

In Figure 2, it may be noted that the experimental and calculated curves begin to depart from one another at humidities of about 50 to 60 percent. Up to these values, the empirical attenuation curve may be used with reasonable accuracy.

| GREEN MOUNTAIN | | | | PARKWAY | | | | MARSHALL SPACE FLIGHT CENTER | | | |
|--------------------------------|--------------------|-------------|---------------|--------------------|-------------|---------------|--------------------|------------------------------|---------------|--------------------|-------------|
| Relative Signal Strength | Pressure In. Hg | Temp. Of | Humidity % | Pressure In. Hg | Temp. Of | Humidity % | Pressure In. Hg | Temp. Of | Humidity % | Pressure In. Hg | Temp. Of |
| 1.80 | 28.70 | 35.0 | 35.0 | 29.60 | 35.0 | 35.0 | 29.60 | 35.0 | 82.5 | 29.60 | 35.0 |
| -0.50 | 28.70 | 40.0 | 80.0 | 29.55 | 40.0 | 80.0 | 29.55 | 40.0 | 97.5 | 29.55 | 40.0 |
| 0.25 | 28.90 | 30.0 | 77.5 | 29.80 | 30.0 | 77.5 | 29.80 | 30.0 | 97.5 | 29.80 | 30.0 |
| 0.26 | 28.95 | 25.0 | 58.0 | 29.90 | 25.0 | 78.0 | 29.90 | 25.0 | 97.5 | 29.90 | 25.0 |
| 0.25 | 28.80 | 30.0 | 52.5 | 29.70 | 30.0 | 75.0 | 29.70 | 30.0 | 98.0 | 29.70 | 30.0 |
| 1.00 | 28.75 | 35.0 | 47.5 | 29.60 | 35.0 | 65.0 | 29.60 | 35.0 | 85.0 | 29.60 | 35.0 |
| 1.25 | 28.85 | 47.5 | 38.0 | 29.70 | 47.5 | 48.0 | 29.70 | 47.5 | 82.5 | 29.70 | 47.5 |
| 0.25 | 28.70 | 52.5 | 62.5 | 29.60 | 52.5 | 55.0 | 29.60 | 52.5 | 82.5 | 29.60 | 52.5 |
| 1.25 | 28.95 | 32.5 | 38.5 | 29.85 | 32.5 | 66.5 | 29.85 | 32.5 | 98.0 | 29.85 | 32.5 |
| 1.75 | 28.85 | 35.0 | 25.0 | 29.75 | 35.0 | 45.0 | 29.75 | 35.0 | 65.0 | 29.75 | 35.0 |

TABLE I

AVERAGE VALUES OF DATA OBTAINED USING A PERIOD OF 12 HOURS.

TABLE 2

COMPOSITE HUMIDITY AVERAGES
USING VALUES OBTAINED AT THE
GREEN MOUNTAIN AND PARKWAY STATIONS

| Relative Signal Strength | Composite Humidity Averages |
|-----------------------------|--------------------------------|
| 0.25 | 67.0% |
| 1.00 | 55.5% |
| 1.25 | 48.0% |
| 1.80 | 35.0% |

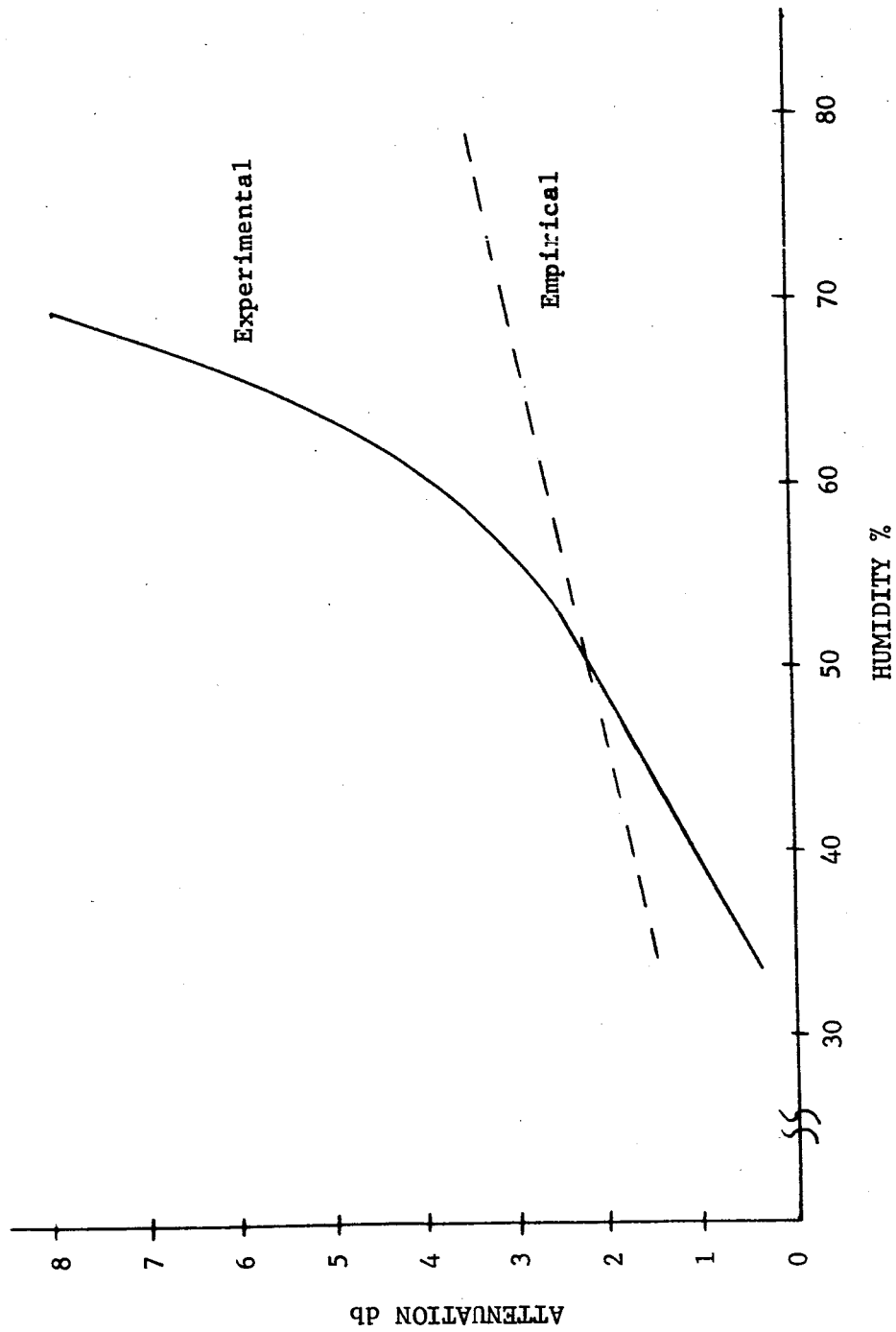


Fig. 2--Attenuation plotted as a function of composite humidity averages.

III. CONCLUSION

Attenuation of the propagated electromagnetic waves at 35 GHz is due primarily to the presence of water vapor in the atmosphere. The effects of temperature and pressure are so small in comparison to that of water vapor that one is not able to attribute any particular effect to these variables. No resonant absorption occurs at the frequency of 35 GHz. The resonant lines for water vapor and oxygen occur at frequencies of 190 GHz and 60 GHz respectively.²

As shown in Figure 2, the curve obtained from the experimental data is reasonably approximated by the empirical equation up to a humidity of about 60 percent. The deviation can be attributed to the fact that water droplets are beginning to form at this level of humidity. The droplets then scatter the beam to such a degree that the level of the received signal is strongly reduced. This accounts for the sharp increase in attenuation with increase in humidity. With measurement made under carefully controlled environmental conditions, this scattering effect could be considerably diminished.